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DR SE-02-A

Volume 3

Interface Control Documents

November 1976

Part 3
AMPS Payload to Instruments ICD

Atmospheric, Magnetospheric and Plasmas in Space (AMPS) Spacelab Payload Definition Study

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Bendix

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ATMOSPHERIC, MAGNETOSPHERIC AND PLASMAS IN SPACE (AMPS) SPACELAB PAYLOAD DEFINITION STUDY.

Prepared for

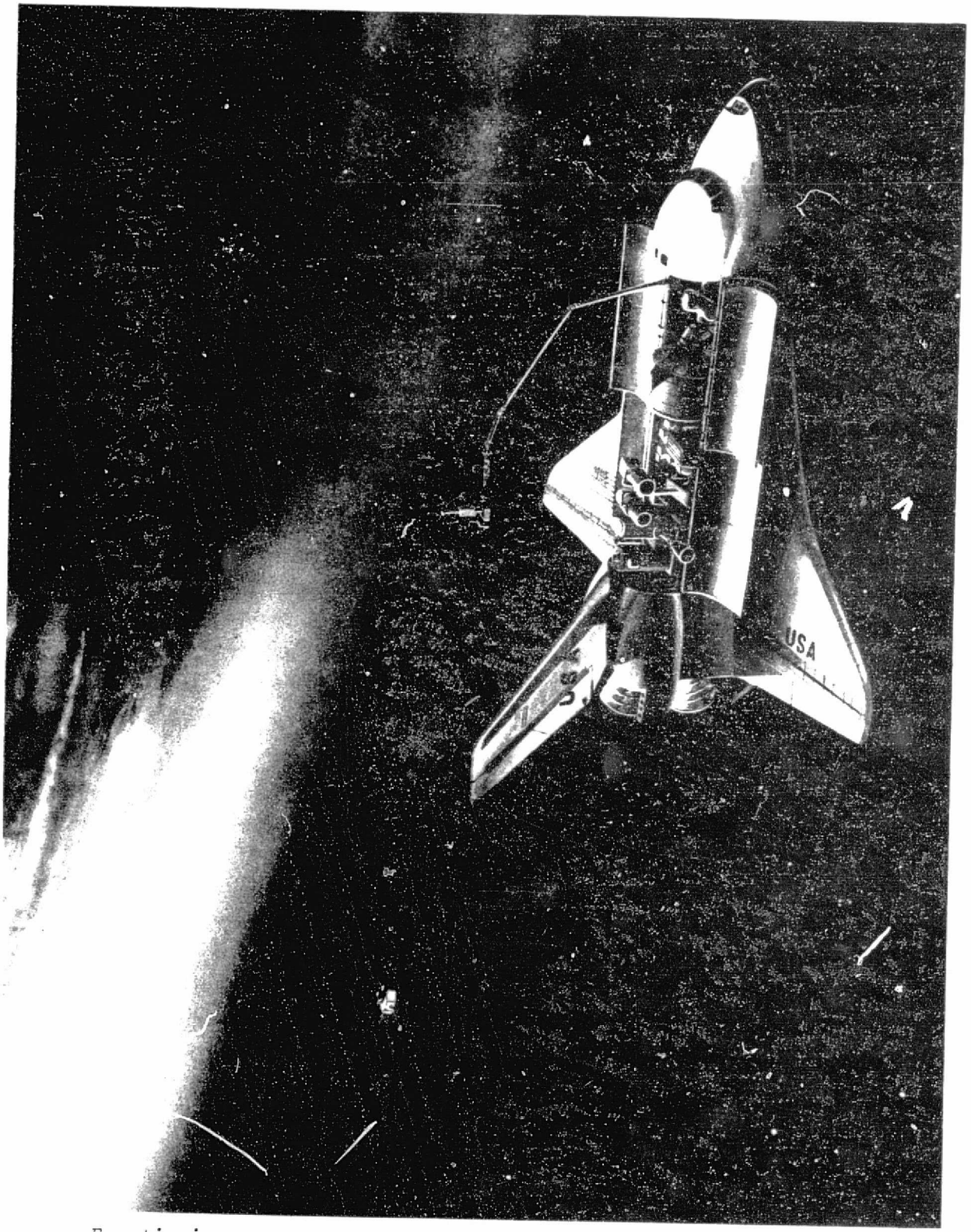
Goddard Space Flight Center
Greenbelt, Maryland 20771



J. T. Keeley
Program Manager
AMPS

MARTIN MARIETTA CORPORATION
P. O. Box 179
Denver, Colorado

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FOREWORD

The AMPS final report is submitted by Martin Marietta in accordance with Data Procurement Document Number 486, Revision A, of Goddard Space Flight Center Contract NAS8-31689.

The AMPS final report consists of seven volumes. They are:

Volume 1	DR MA-05-A	Executive Summary Report
Volume 2	DR SE-01-A	Mission Support Requirements Document
Volume 3	DR SE-02-A	Interface Control Documents
	Part 1	AMPS Payload to Shuttle ICD
	Part 2	AMPS Payload to Spacelab ICD
	Part 3	AMPS Payload to Instruments ICD
Volume 4	DR SE-03-A	Specifications
	Part 1	AMPS Program Specification
	Part 2	Labcraft Payload General Specification
	Part 3	Labcraft Instrument Systems General Specification
Volume 5	DR SE-04-A	Deleted per Paragraph I, Attachment A, Request for Proposal under Changes Clause, dated 8/31/76
Volume 6	DR SE-05-A	Instruments Functional Requirements Document
Volume 7	DR MA-04-A	Program Analysis and Planning for Phase C/D Document
Volume 8	DR MF 003R-A	Program Study Cost Estimates Document

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1. PURPOSE

The AMPS to Instruments Interface Control Document defines the general instrument interface requirements and provides the format for specific instrument ICDs. Each individual AMPS instrument will have its own ICD to AMPS which will use this document's outline and informational content, except where exceptions will be noted. Figure 1-1 illustrates the AMPS instruments' interfaces and the program scope of the interface activity. Instruments will interface with AMPS Flight Support Equipment (FSE), Ground Support Equipment (GSE), with the Spacelab, and with the Space Shuttle Vehicle. Interface control is required from the ground handling phase of the program through and including the entire mission phases.

This document contains all of the interface subjects anticipated by the AMPS program; additional data will be included as the program matures. A minimum of cross referencing to other program documents has been made, so that this ICD alone will control the instruments' interfaces. The document will be prepared and maintained by the prime contractor with inputs from the instrument developer under the cognizance of the AMPS project team. The prime contractor's knowledge of the STS, enables him to define and control the interfaces from development through operational phases of the AMPS program. Our experience in documentation will provide a standardized format, non-redundant and simplified control of the interfaces and ultimately will produce the most cost effective approach to interface control.

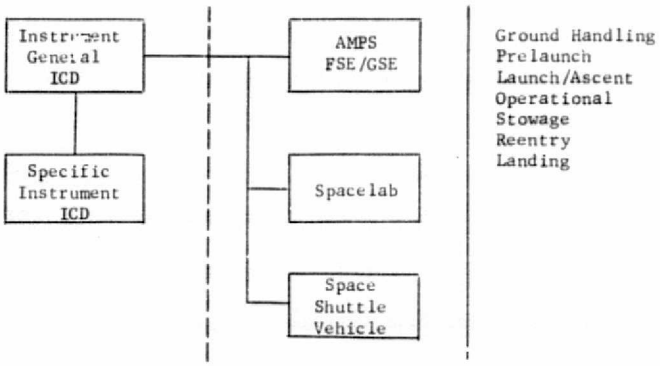


Figure 1-1 AMPS Instrument Interfaces

Figure 1-2, the AMPS Top Level Requirements Tree, illustrates the interrelationship of all AMPS technical documents. This Level III ICD is shown shaded and the other two Level II ICDs to the Space Shuttle Vehicle and Spacelab are also shown.

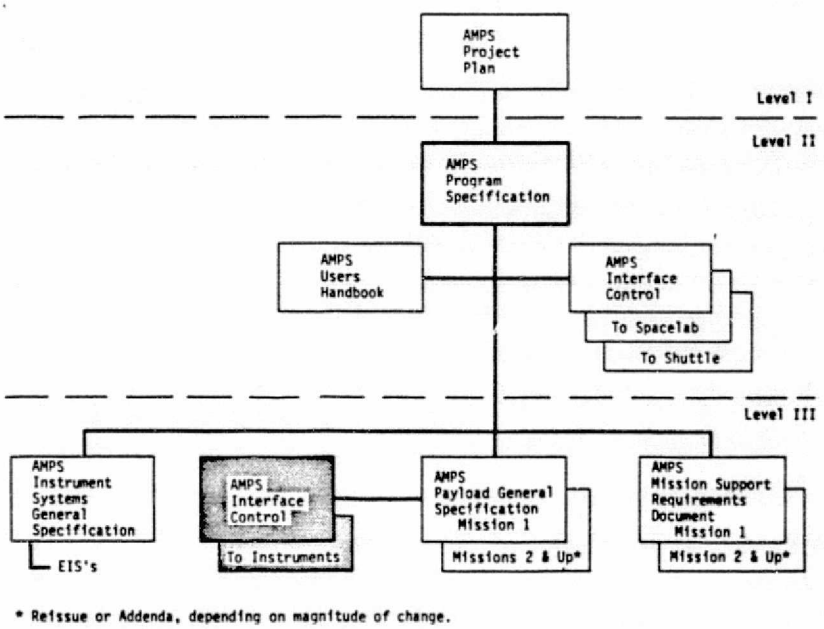


Figure 1-2 AMPS Top Level Requirements Tree

1.1 SCOPE

This document contains general physical, functional and operational interface control requirements for instruments on the first AMPS payload, as it is currently defined. Included are the interface specifications to satisfy ground handling, prelaunch, launch, stowage, operation, and landing activities. Applicable supporting documentation to implement this document is also contained.

2. APPLICABLE DOCUMENTS

End Item Specifications for specific instruments (when available, until they are available IFRDs will be used); AMPS Program Specifications (DR-SE-03) 11/5/76; Bonding, Electrical and Lightning Protection for Aerospace Systems, MIL-B-5087B, 10/15/64, Ammendment 2, 8/31/70; Clean Room and Work Station Requirements, Fed-Std-209B, 4/24/63; Electromagnetic Interferences Characteristics for Equipment, MIL-STD-461A, 8/1/68; Measurement of Electromagnetic Interference Characteristics, MIL-STD-462; JSC-Space SP-R-0022.

3. INTERFACE REQUIREMENTS

3.1 MECHANICAL/STRUCTURAL

3.1.1 INSTRUMENT ENVELOPE, LOCATION AND CENTER OF GRAVITY

The instrument's envelope, showing its relationship to the AMPS Structure will be shown here. The sketch will also denote the center of gravity. For instruments containing modular construction individual outlines will be shown. Drawings will contain a sufficient level of detail to satisfy both sides of the mechanical interface.

Tolerances on typical dimensions are shown in Figure 3.1-1 below, and are to be used unless they are unsatisfactory for a particular application.

Measurement Parameter	Tolerance
Center of Gravity	$\pm$0.5 Inch
Envelope	Maximum Sizes
Location	$\pm$0.5 Inch
Flatness	.001 Inches/Inch
Parallelism, Perpendicularity	.002 Inches/Inch
Surface Finish	63 Microinches
2 Place Dimensions	$\pm$0.03
3 Place Dimensions	$\pm$0.010
Angles	$\pm\frac{1}{2}^{o}$

Figure 3.1-1 Standard Tolerances

Maximum envelopes will be dependent upon the location of the instrument.

Location	Maximum Envelope
Minimount	TBD
IPS	TBD
SIPS (Standard Canister	.99 M x .99 M x 3.2 M
Environmental Canister (MPM)	.76 M Dia x 1.55 M
Pallet	3.63 M Dia x 2.87 M
RMS	TBD
Internal to Spacelab	TBD
Deployed Instrument	TBD

3.1.1.1 GROUND HANDLING DRAWINGS

This drawing will show the attach points of any mechanical GSE/handling equipment to the instrument. For installation/removal of an instrument from the payload, the GSE should be capable of being connected with the instrument attached to the payload, and still provide access to remove the instrument. Test connectors and their intended use will be identified.

3.1.1.2 STOWAGE

This drawing will show interfaces for stowed instrument equipment. Attachment mechanisms for caging devices will be illustrated. If the configuration is different for pre and post operational stowage, separate interface drawings must be included.

3.1.1.3 OPERATIONAL

This sketch will show the operational configuration of the instruments. Attention will be given to fields-of-view, clearance envelopes for deployed or retrieved instruments, ejection mechanisms, etc. Instruments which extend beyond the payload bay (60 ft length x 15 ft diameter) with the doors open may include the capability for an ejection mechanism. (Jettison capability may be supplied either as instrument hardware or flight support equipment).

3.1.2 INSTRUMENT WEIGHTS

This section of the specific instrument ICDs will define the instruments' weights. The tolerance on weights will vary dependent on the instruments total weight.

Instrument Classification	Weight	Tolerance
Light	0-10 Kg	$\pm$.05 Kg
Medium	10-100 Kg	$\pm$0.1 Kg
Heavy	$>$100 Kg	$\pm$0.5 Kg

3.1.2.1 WEIGHT LOCATION LIMIT

Maximum Weights for Instruments will vary dependent on the location.

Location	Weight Limit
Minimount	500 Kg
IPS	2000 Kg
SIPS	500 Kg (Each Yoke)
Environmental Canister (MPM)	286 Kg
Pallet (Single) (2 and 3 Pallet Train)	5000 Kg 3118 Kg
RMS	TBD
Internal to Spacelab Module	TBD
Deployed Instrument	TBD

3.1.3 INSTRUMENT MOUNTING

Instruments will be mounted directly to the pallets, to intermediate structure, to other instruments, or in the Spacelab Module depending on operational or structural considerations.

Instruments to be deployed or retrieved via the RMS will have a standardized configuration to interface with the RMS end effector. The configuration is TBD.

3.1.3.1 PALLET MOUNTED INSTRUMENTS

Instruments directly mounted to pallets will mount at the hardpoints shown in Figure 3.1-2. There are 24 standard hardpoints each providing a spherical nut with 12 mm diameter metric thread, bolted to the pallet structure.

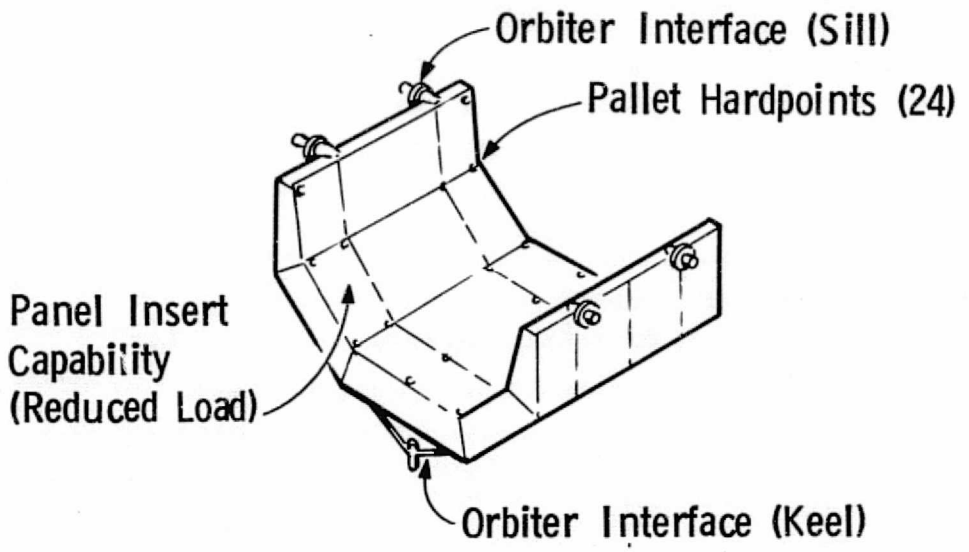


Figure 3.1-2 Pallet Showing Hardpoints

3.1.3.2 INSTRUMENTS MOUNTED TO INTERMEDIATE STRUCTURE

This section will describe the mounting techniques for instruments mounted to structure intermediate to the pallet and the instrument. It will outline mounting provisions for the minimount, IPS, SIPS platforms, the thermal canister, intermediate racks. Mounting of items such as pyrotechnics, ejection mechanisms will be covered here.

3.1.3.3 INSTRUMENTS MOUNTED TO OTHER INSTRUMENTS

This section will describe mounting provisions and constraints imposed when one instrument mounts to another instrument.

3.1.3.4 INSTRUMENTS MOUNTED INTERNAL TO THE SPACELAB MODULE

This section will describe standard interfaces required for instruments or instrument components mounted internal to the Spacelab Module.

3.1.3.5 THERMAL BLANKET INSTALLATION

This section will standardize the mounting techniques between thermal blankets and instruments mounted in the pallet section.

3.1.4 INSTRUMENT ELECTRICAL CONNECTORS

This section will define standardized power and signal connectors. Connectors will be selected so the male is on the instrument and the female is on the cable end of the interface. Connectors will be keyed for positive orientation and they will be located on the instrument so they are accessible after the instrument has been mounted to the Spacelab. A list of standardized connectors to be used by the AMPS instruments is TBD. Test connectors will be treated in the same manner as flight connectors.

3.1.5 INSTRUMENT PLUMBING

This section will describe interface fittings between instruments

and plumbing systems, such as pneumatics, cryogens, and fluids. Standard fittings will be described whenever possible.

3.1.6 UTILITIES ROUTING

AMPS instrument utilities routing (signal, power and fluid lines) from pallet-to-pallet, within a pallet, inside the module and module-to-pallet will be described in this section. Routing of cabling to the platforms will be standardized, wherever practical, as in the case of the SIPS, which is center mounted on the pallet for the first two AMPS flights.

3.1.7 INSTRUMENT ALIGNMENT AND FIELD-OF-VIEW

This section will describe interface alignment of the instrument to either the pallet structure or the Spacelab/Orbiter, fields-of-view of instruments, both fixed and scanning, and co-alignment of one instrument to another. Alignment tolerances will be standardized depending on whether an instrument is hard mounted to pallet racks, platform mounted, deployed, etc.

3.1.8 INSTRUMENT LOADS

This section will define the load directions, paths for limit and ultimate loads.

3.1.8.1 PALLET MOUNTED INSTRUMENTS

For pallet mounted instruments a table will be provided that will list the load capabilities for each of the hardpoints on the pallet structure with the exception of the hardpoints on the pallet sill. The capabilities of each hardpoint will be shown in the X, Y and Z directions both for flight (limit loads) and crash (ultimate loads) cases.

3.1.9 INSTRUMENT VENTING/PRESSURE CONTAINERS

3.1.9.1 INSTRUMENT VENTING

Each pressure system of instrument hardware that is vented due to design considerations shall be capable of withstanding the stresses created by the pressure differentials of launch/re-entry. If the instrument system is vented the contamination level produced shall not be greater than TBD, dependent upon instrument location.

3.1.9.2 INSTRUMENT PRESSURE CONTAINERS

If design considerations, such as a susceptibility to high stress or coronal discharge conditions creates a need for pressurizing instrument system containers, the containers should be pressurized with an inert gas at a pressure level within the capabilities of the material design.

3.1.10 MATERIAL SELECTION

Materials selected for use on instruments must comply with approprate NASA materials lists and must not give off any toxic or noxious fumes, or dust in such concentration as to impair crew performance or safety. Materials shall be chosen to minimize or contain generation of loose particulate matter, liquid or gaseous contamination which may be detrimental to instrument, Spacelab, or Shuttle operations. Materials shall be selected for low outgassing characteristics. Selection criteria shall be 1% total mass loss and 0.1% volatile condensible material as defined in JSC Specification SP-R-0022.

3.1.11 CLEANLINESS

3.1.11.1 SURFACE CONTAMINATION

Instruments shall be designed so that surfaces are free of visible contamination, such as oil, grease, dust, water, scale or other foreign particles. Instrument design will be compatible with a class 100,000 clean room environment.

3.1.11.2 SURFACE FINISHES

External surfaces shall be free of burrs, sharp edges or protrusions.

3.2 ELECTRICAL

3.2.1 VOLTAGE INPUT CHARACTERISTICS

This section will define the standard voltages delivered through Spacelab via the AMPS power distributor to the instruments. The voltages are anticipated to be 28 vdc $\pm$ 4 vdc and 115/200 $\pm$ 5% vac, 3$\emptyset$, 400 Hz $\pm$ 1%. It will also specify voltage needs of instruments which require battery supply.

3.2.2 ALLOWABLE VOLTAGE TRANSIENTS

This section will define the standard transients voltage levels from the steady state and the duration of the transients at the instrument interface.

3.2.3 OVER AND UNDERVOLTAGE BEHAVIOR

Instruments shall be designed to survive steady state undervoltages of 22.5 vdc and overvoltages of 50 vdc.

3.2.4 RIPPLE VOLTAGES

Instrument shall be designed to operate with the following ripple voltage characteristics.

a. 0.9 v peak to peak (30 Hz to 7 KHz) falling 10 db per decade to 0.28 v peak-to-peak at 70 KHz, thereafter remaining constant, to 400 MHz.

b. 1.6 v peak-to-peak over a broadband of 30 Hz to 50 KHz, then decreasing linearly with frequency at a rate of 40 db per decade to 500 KHz, thereafter remaining constant to 50 MHz.

3.2.5 AVAILABLE POWER

This section will specify the power available for each instrument in terms of peak watts or ampere-hours.

3.2.6 INTERFACE BLOCK DIAGRAM

This section will contain a schematic block diagram illustrating the main elements of the electric interfaces.

3.2.7 INTERFACE WIRING SCHEMATIC

This section will tabulate pin functions, circuit origination and termination points, voltage levels and load characteristics.

3.2.8 CIRCUIT RETURN GROUNDING

This section will define grounding and isolation of power circuit returns and signal circuit returns.

3.2.8.1 POWER CIRCUIT RETURN SYSTEM

Instruments shall have all primary power returns isolated from signal by a minimum of 1 megohm dc for signals circuits. All return lines shall be dc-isolated from structure. DC power return lines shall be isolated from structure by 1 megohm dc resistance.

3.2.8.2 SECONDARY POWER/SIGNAL RETURNS

The reference for interfaces between instruments and secondary power/signal returns shall be isolated from the instrument case by 4000 Ω dc, or greater.

3.2.9 ELECTRICAL BONDING

Instrument cases shall be electrically bonded to the vehicle structure per the requirements of MIL-B-5087B.

3.2.10 SHIELD GROUNDS

Wire harness shields external to instruments, requiring grounding at the instrument, shall have provisions for grounding the shields to the instrument through the connector. Instrument connectors shall be bonded to the instrument case and on bulkhead mount to a dc resistance less than 2.5 milliohms.

3.2.11 GSE TEST POINTS

This section will describe the GSE test point functions and will include a functional block diagram of each piece of GSE including its operational connections.

3.2.12 CIRCUIT PROTECTION

This section will describe current limiting requirements and circuit protection, such as circuit breakers and fusing requirements.

3.2.13 ELECTROMAGNETIC COMPATIBILITY

Instruments shall be capable of operation in accordance with the electromagnetic compatibility requirements of MIL-B-5087B and JSC SL-E-0002, Rev A, JSC-07636.

3.2.13.1 CONDUCTED INTERFERENCE

This section will define the conducted emissions and susceptibility levels at the instrument interface.

3.2.13.2 RADIATED INTERFERENCE

Instruments shall be designed to be compatible with the radiation environment of the payload bay.

3.2.13.2.1 MAGNETIC FIELDS

Shall be limited to less than 140 db above 1 pico tesla (30 Hz to 2 KHz), falling 40 db per decade to 50 KHz. The dc fields are TBD.

3.2.13.2.2 ELECTRIC FIELDS

Shall be limited to levels of 0.5 volts from 15 KHz to 10 GHz except at frequencies of Orbiter installed transmitters.

3.2.13.3 INSTRUMENT PRODUCED INTERFACE ENVIRONMENT

The instruments shall not produce interference levels, either conducted or radiated in excess of the following:

CE-01	TBD
CE-03	
RE-02	
RE-04	
TT-01	

3.3 THERMAL

3.3.1 TEMPERATURE

This section will describe the temperature limits for the instruments.

3.3.2 ACTIVE THERMAL CONTROL SYSTEM

This section will define the coolant loop flow rates, fluid pressures, and heat exchanger characteristics (inlet and outlet temperatures, and heat transferred) for a particular instrument, and instrument external temperatures (limited to 45°C). The active thermal control system (see Figure 3.3-1) can transfer 8.5 Kw maximum continuously to the Orbiter and an additional 3.9 Kw for fifteen minutes every three hours.

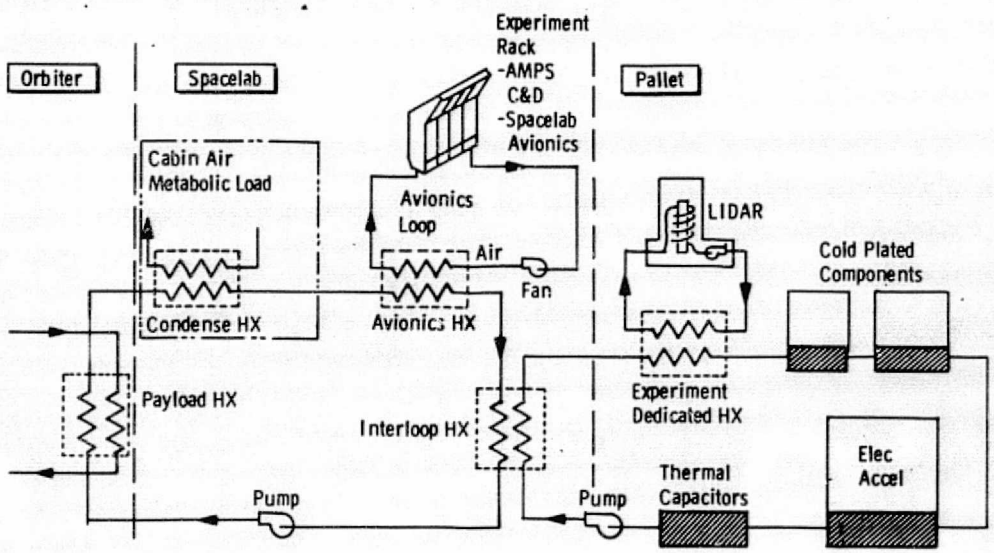


Figure 3.3-1 TCS Schematic

The heat generated by Spacelab and its payload inside the module is collected by a water cooling loop which transfers heat to the Orbiter heat exchanger. A freon loop is used to collect heat generated on the pallet. The freon loop interfaces with the water loop through the Spacelab interloop heat exchanger located outside the module on the forward end cone.

The water loop contains several heat exchangers and cold plates in series. The condensing heat exchanger is used in the cabin air cooling loop that controls module air temperature. An experiment heat exchanger is provided to offer liquid cooling capability for experiments. Then follows the avionics heat exchanger which is used in the avionics air cooling loop which cools rack mounted experiment equipment and some subsystem equipment.

The freon loop provides cooling for pallet mounted instruments through cold plates. To accommodate peak loads, thermal capacitors can be mounted on the cold plates.

3.3.2.1 CABIN AIR LOOP

This section will define the heat rejection characteristics of any instrument requiring air cooling inside the module. The instruments' location will be specified whether in the center aisle, at the optical window, etc. The heat generated by instruments is limited to 1 Kw. Cabin air temperatures, which can be adjusted within $18^{o}C$ to $27^{o}C \pm 1.1^{o}C$ would be specified.

3.3.2.2 AVIONICS AIR LOOP

This section will define the heat rejection characteristics of rack mounted instruments which require air cooling.

The avionics loop establishes air flow through the ducting system and the racks and interfaces with the water loop.

Instrument cooling will be specified, whether duct or surface cooling is required. The approximate range of instrument heat that can realistically be accommodated is, in the range of 1.7 - 4.2 Kw, resulting in cool air supply temperatures of about 37 - 41.5°C (under peak load conditions the outlet temperature can go up to about 50°C).

3.3.2.3 EXPERIMENT HEAT EXCHANGER

The experiment heat exchanger is designed for an experiment heat transfer of 4 Kw to the water loop. The interface to instruments is at the coolant liquid inlet and outlet connectors of the heat exchanger. This section will define inlet and outlet fluid temperatures and the heat transferred. (Note: AMPS uses an experiment heat exchanger in the freon loop.)

3.3.2.4 COLD PLATES

There are nominally up to eight cold plates, mounted in series, which are part of the freon loop. The panels fit on the 48° section of the pallet segments; they may all be mounted on one pallet segment or distributed over several pallet segments. Instruments are mounted to the pallet panel and cold plate with titanium bolts, with thermal stand-offs between cold plate and pallet panel, to limit heat transfer between pallet and the instrument. The cold plates are designed for a nominal heat rejection capability of 1 Kw. Heat from instruments is transferred in the area around the mounting holes which are used to

bolt instruments to the cold plate and pallet panel. The design foresees a heat transfer of 13 W per bolt with a conductance of 1 W/°C. The use of thermal filler to establish optimum thermal conduct might be required. The maximum heat transfer to the coolant loop is expected to be 4.85 Kw maximum. The freon inlet temperature at the first cold plate will normally be not below 24°C; the outlet of the last cold plate can go as high as 43°C. This section will specify the heat transferred to the cold plates by the instruments.

3.3.3 THERMAL CONTROL CANISTERS

This section will define thermal interface characteristics for platform mounted instruments which are thermally controlled by means of a thermal canister.

3.3.4 HEATER REQUIREMENTS

For instruments requiring heaters, the heater power will be described here.

3.3.5 PASSIVE THERMAL INTERFACES

3.3.5.1 THERMAL SURFACE COATINGS

This section will describe the absorption and emittance characteristics of AMPS/instrument surfaces. The α/ϵ ratio should be TBD.

3.3.5.2 THERMAL BLANKETS

This section will define the thermal characteristics of thermal blankets which interface with instruments.

3.3.5.3 THERMAL INSULATORS, STANDOFFS

Any thermal insulators/standoffs required by the instruments will be defined here.

3.3.6 ORBITER FLIGHT DECK THERMAL CONTROL INTERFACES

The Orbiter flight deck provides an average cooling capability of 0.35 Kw during on-orbit operational phases. This section will describe the heat transfer characteristics of instruments located in this section of the Orbiter.

3.4 NATURAL ENVIRONMENTS

This section will address the natural environments to which pallet mounted instruments will be exposed for both preflight and in orbit.

3.4.1 TEMPERATURE

Operational Phase	T min. (°C)	T max. (°C)
Ground	- 31	66
Launch/Ascent	4.5	65.5
Doors Closed	- 50	70
Orbit Doors Open	-150	70
Re-Entry	-100	100
Post Landing	-100	100

Figure 3.4-1 Pallet Surface Temperatures

3.4.2 SPACE THERMAL ENVIRONMENT

Environmental Parameter	Unit	Maximum	Nominal	Minimum
Solar Radiation	W/m^2 ($Btu/h\text{-}ft^2$)	1440.5 (457)	1352.2 (429)	1264.0 (401)
Earth Global Albedo	Percent (%) of Solar Radiation	42	30	18
Earth Thermal Radiation	W/m^2 ($Btu/hr\text{-}ft^2$)	278.6 (88.4)	236.4 (75.0)	194.2 (61.6)
Space Sink Temperature	K	----	2.7 K	----

Figure 3.4-2 Space Thermal Environment

3.4.3 FUNGUS

Temperatures above 68°F and relative humidities above 75% are conducive to high growth rates of fungi (including mold) and bacteria and the design should utilize non-fungi nutrient materials.

3.4.4 HUMIDITY

For design purposes, 0 to 100 percent relative humidity at the temperature extremes defined herein shall be the consideration.

For detailed definition of the extreme surface humdity, the following is provided:

a. High Temperature/High Vapor Concentration - The following extreme humdity cycle of 24 hours should be considered in design: 3 hours of 99°F air temperature at 50 percent relative humidity and a vapor concentration of 9.7 gr/ft^3; 6 hours of decreasing air temperature to 76°F with relative humidity increasing to 100 percent (saturation); 8 hours of decreasing air temperature to 70°F, with a release of 1.7 gr of water per cubic foot of air, humidity remaining at 100 percent; and 7 hours of increasing air temperature to 99°F and a decrease to 50 percent relative humidity.

b. A vapor concentration of 2.1 gr/ft^3, corresponding to a dew point of 32°F at an air temperature of 100°F and a maximum relative humdity of 26 percent at an air temperature of 70°F remaining 20 hours of each 24 hours for 10 days.

c. Low Temperatures/Low Vapor Concentration - A vapor concentration of 0.9 gr/ft^3, with an air temperature of 11^{o}F and a relative humidity between 98 and 100 percent for a duration of 24 hours.

3.4.5 LIGHTNING

Lightning protection criteria for the Space Shuttle System is defined in document JSC-07636 and may be used as a guide for payload design where lightning protection is desired. The expected magnetic field levels within the payload bay, due to a lightning strike to the Orbiter, are 280 amperes/meter for the aperture component and 150 amperes/meter (no payload) or 300 amperes/meter (payload installed) for the diffusion component. These field levels are based on a 200,000 amperes strike with a 2 microsecond rise time.

3.4.6 SALT SPRAY

Design Model - 1.0 percent by weight salt (NaCl) solution for 30 days.

3.4.7 SAND/DUST

Equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 grams per cubic foot.

3.4.8 SPACE NUCLEAR RADIATION

The natural nuclear radiation environment in terrestrial space consists of:

3.4.8.1 GALACTIC COSMIC RADIATION (MAINLY PROTONS)

Composition: 85% protons, 13% alpha particles, 2% heavier nuclei.

Energy Range: 10^7 to 10^{19} electron volts; predominant 10^9 to 10^{13}.

Flux outside earth's magnetic field: 0.2 to 0.4 particles/CM^2/steradian/sec.

Integrated yearly rate: approximately 1 x 10^8 protons per sq cm.

Integrated yearly dose: approximately 4 to 10 rads.

3.4.8.2 TRAPPED RADIATION (PROTONS, ELECTRONS)

Energy: Electrons >0.5 MeV, Protons >34 MeV

Peak Electron Flux: $>10^8$ Electrons per sq cm per sec (omni-directional)

Peak Electron Flux Altitude: approximately 1000 n mi at equator.

Peak Proton Flux: 10^4 to 10^5 protons per sq cm per sec (omni-directional)

Peak Proton Flux Altitude: approximately 1900 n mi at equator.

3.4.8.3 SOLAR PARTICLE EVENTS

Composition: Energetic protons and alpha particles

Occurence: Sporadically and lasting for several days

Particle Event Model (free space):

$$\text{Protons: } Np\ (>T) = \begin{cases} 7.25 \times 10^{11} T^{-1.2} & 1\ \text{MeV} \leqslant T \leqslant 10\ \text{MeV} \\ 3.54 \times 10^{11} E^{-P(T)/67} & 10\ \text{MeV} \leqslant T \leqslant 30\ \text{MeV} \\ 2.64 \times 10^{11} E^{-P(T)/73} & T > 30\ \text{MeV} \end{cases}$$

$$\text{Alphas: } N\alpha\ (>T) = \begin{cases} Np(>T) & T < 30\ \text{MeV} \\ 7.07 \times 10^{12} T^{-2.14} & T \geqslant 30\ \text{MeV} \end{cases}$$

Where $NP(>T)$, $N\alpha(>T)$ = protons/cm^2, alphas/cm^2 with energy $>T$

$P(T)$ = particle magnetic rigidity in mV

$$P(T) = \frac{1}{Ze}\left[T(T + 2m\,C^2)\right]^{\frac{1}{2}}$$

Ze = 1 for protons, 2 for alphas

$m\,C^2$ = 938 MeV for protons, 3728 MeV for alphas

3.4.9 METEOROIDS

With the payload bay doors open, the meteoroid model encompasses particles of cometary origin in the mass range between 1 and 10^{-12} grams for sporadic meteoroids and 1 to 10^{-6} grams for stream meteoroids.

3.5 INDUCED ENVIRONMENTS

This section will define the induced environments which AMPS

instruments will be subjected to during prelaunch, launch, ascent and re-entry, stowage and operational phases of any mission.

3.5.1 GROUND HANDLING AND TRANSPORTATION

3.5.1.1 TEMPERATURE

When the payload bay doors are opened, the temperature in the Orbiter Processing Facility building areas will be controlled to $75 \pm 3^{\circ}F$.

When the payload bay doors are opened, the purge system supplies conditioned air to the payload bay during prelaunch operations until 80 minutes prior to Orbiter cryogenics loading except during switch over between mobile and facility GSE at the OPF, VAB, PAD, and during hoisting operations in the VAB. Starting at 80 minutes prior to Orbiter cryogenics loading, GN_2 will be supplied to provide an inert payload bay atmosphere through lift off. Two supply pressure levels are provided just upstream of the ground portion of the umbilical disconnect:

a. The 2.5 psig system supplies either air or GN_2 to the payload bay during all operations not involving cryogenic payloads.

b. The 10.0 psig system supplies only GN_2 and is used for cryogenic payloads only.

Within thirty minutes following touchdown the purge system

supplies conditioned air to the payload bay utilizing a 2.0 psig supply pressure.

The purge gas will be either air or GN_2 nominally class 100, guaranteed class 5000 (HEPA) filtered with 15 ppm or less hydrocarbons based upon a methane equivalent.

3.5.1.2 SHOCK

During handling payload equipment may experience as much as a 20g terminal sawtooth shock pulse of an 11 millisecond duration in each of three orthogonal axes (6 directions). All components shall be designed to withstand this basic design shock spectrum.

3.5.1.3 ACCELERATION

2g vertical within a plus or minus cone angle or 20 degrees.

3.5.1.4 VIBRATION

The vibration spectrum that the payloads are expected to experience is a minimum of four (4) sweeps at 1/2 octave per minute at the following levels (sinusoidal motion).

2-5 Hz	at	1.0 inch (25.4 mm) double amplitude
5-26 Hz		1.3 g peak
26-50 Hz		0.036 inch (0.91 mm) double amplitude
500-1000 Hz		5 g peak

3.5.2 FLIGHT ENVIRONMENTS

3.5.2.1 PRESSURE

The Orbiter cargo bay is vented during the launch and entry phases, and operates unpressurized during the orbital phase of the mission. Typical pressure histories for the cargo bay during ascent and descent are shown in Figures 3.5-1 and 3.5-2.

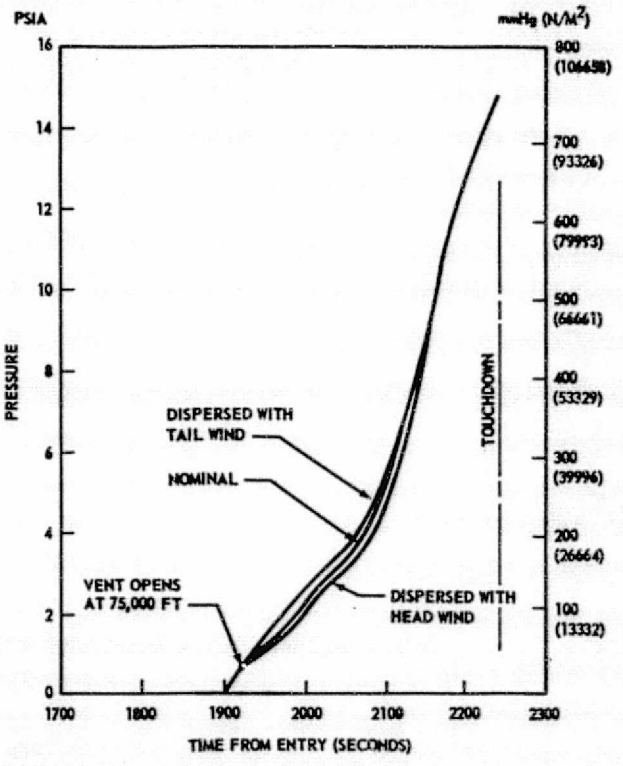


Figure 3.5-1 Orbiter Cargo Bay Internal Pressure History During Ascent

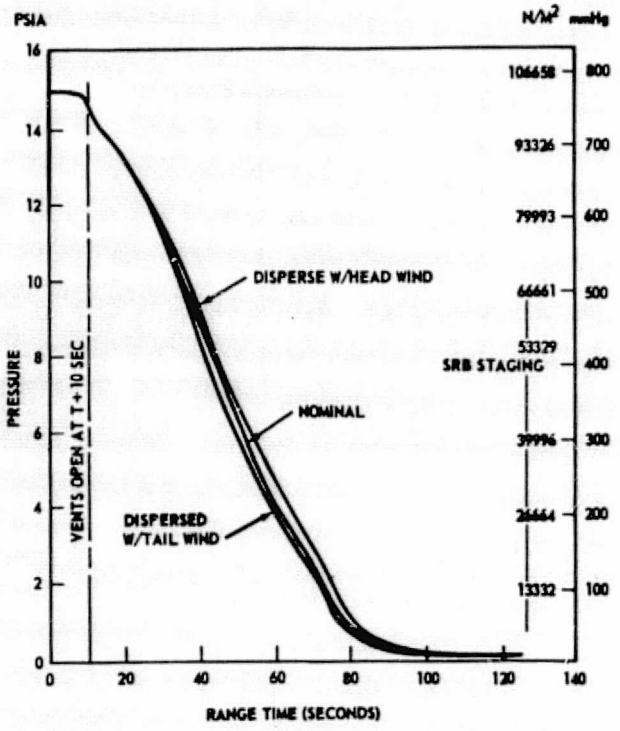


Figure 3.5-2 Orbiter Cargo Bay Internal Pressure History During Entry

3.5.2.2 VIBRATION

3.5.2.2.1 SINUSOIDAL VIBRATION

Instruments mounted in the pallet will be exposed to an environment equivalent to the following Table 3.5-1.

Table 3.5-1 Sinusoidal Vibration Level

Axes	Frequency	Level
X	5 - 8.5 Hz 8.5 - 35 Hz 35 - 50 Hz	20 mm peak-to-peak 3 g 0 to peak 1 g 0 to peak
Y Z	5 - 8.5 Hz 8.5 - 35 Hz	20 mm peak-to-peak 3 g 0 to peak
Sweep Rate:	2 Oct/min.	5 Sweeps up and down

3.5.2.2.2 RANDOM VIBRATION

Maximum vibration levels occur for approximately 6 seconds during the launch phase. Instruments mounted on the pallet will be subjected to vibration arising from the overall acoustic level inside the cargo bay, and a very minor degree to vibration transmitted through the Orbiter/Pallet mounting fixtures into the pallet structure. Instruments attached to pallet hardpoints are subjected to vibration generated by the adjacent panels, which are excited by the overall acoustic noise level within the payload bay. The actual vibration level to which a hardpoint mounted instrument is exposed depends on equipment mass, number of hardpoints used, additional masses attached to adjacent panels, surface of considered equipment, etc., therefore, it is necessary to perform a payload accommodation study for instruments mounted on pallet hardpoints to define the vibration levels.

3.5.2.3 ACOUSTIC NOISE

The estimated acoustic spectrum inside the cargo bay during launch is assumed to be the same for all module and pallet locations and is shown in Figure 3.5-3.

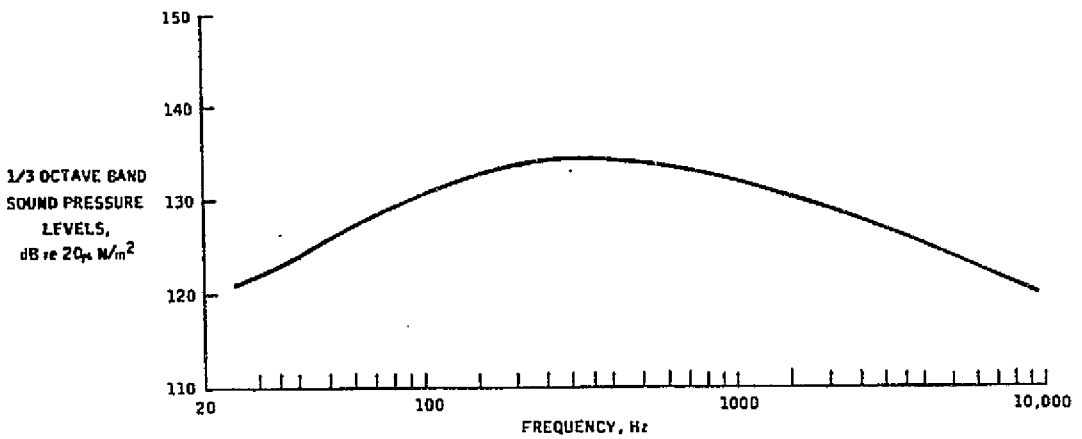


Figure 3.5-3 Analytical Prediction of the Acoustic Spectrum in the Orbiter Cargo Bay

The spectrum produces an integrated overall sound pressure maximum level of 145 db occurring at lift off and decreasing with time very rapidly as shown in Figure 3.5-4.

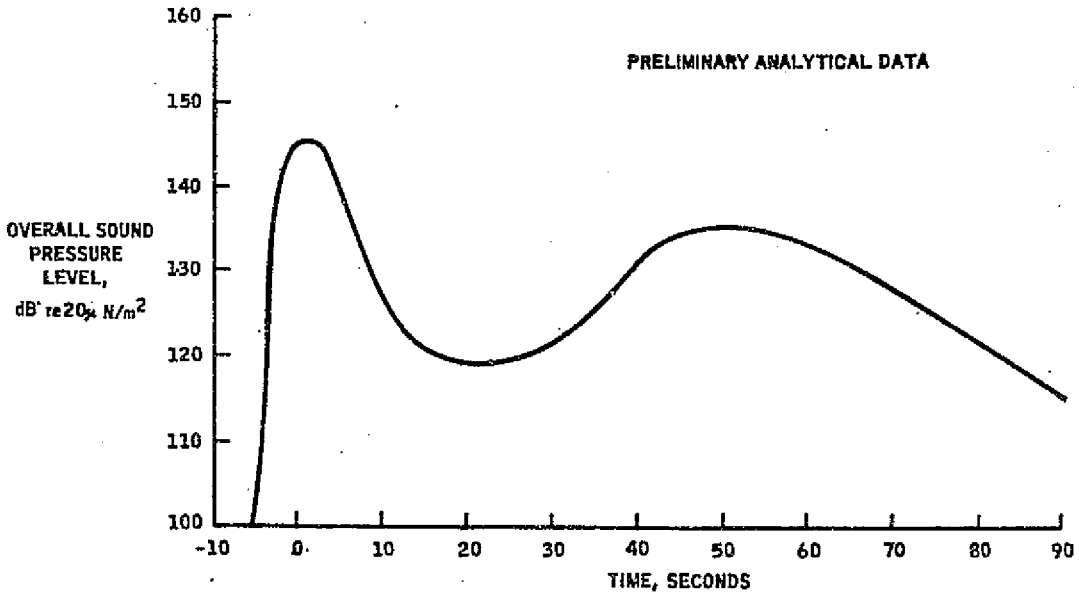


Figure 3.5-4 Acoustic Noise History in the Orbiter Cargo Bay

3.5.2.4 SHOCK

a. Pyro Shock: TBD

b. Landing Shock: Rectangular pulses of the following peak accelerations will be as defined in Table 3.5-2 which is generated by the Orbiter during landing operations. These levels are applicable at the instrument mounting plane in the $+Z_o$ direction only.

c. On-Orbit Operations: If an emergency EVA is required this section will identify survival requirements for a worst case kick-load generated by a suited crewman.

Table 3.5-2 Landing Shock

Acceleration (g Peak)	Duration (Milliseconds)	Applications Per 50 Missions
0.23	170	11
0.28	280	19
0.35	330	16
0.43	380	10
0.56	350	5
0.73	320	2
1.80	260	1

3.5.2.5 ACCELERATION

Maximum expected accelerations (limit load factors) are given in Table 3.5-3.

Table 3.5-3 Limit Load Factors (g's) and Angular Accelerations (RAD/SEC^2)

Condition	$\ddot{X}$	$\ddot{Y}$	$\ddot{Z}$	$\ddot{\phi}$	$\ddot{\theta}$	$\ddot{\psi}$
Lift Off	- 1.6 $\pm$ 1.3	$\pm$ 0.8	- 0.1 $\pm$ 1.0	$\pm$ 0.15	$\pm$ 0.1	$\pm$ 0.1
High Q Boost	- 1.8 $\pm$ 0.2	$\pm$ 0.5	$\pm$ 0.6	$\pm$ 0.15	$\pm$ 0.1	$\pm$ 0.1
Max Boost	- 3.0 $\pm$ 0.15	$\pm$ 0.2	- 0.3	$\pm$ 0.1	$\pm$ 0.1	$\pm$ 0.1
Orbiter Max Load	- 3.0 $\pm$ 0.15	$\pm$ 0.2	- 0.75	$\pm$ 0.1	$\pm$ 0.1	$\pm$ 0.1
Entry and Descent Maneuvers						
+ Pitch	1.1	0.0	2.5	0.0	- 0.1	0.0
- Pitch	0.6	0.0	- 1.0	0.0	0.0	0.0
$\pm$ Yaw	1.0	$\pm$ 1.25	1.0	0.0	0.0	$\pm$ 0.2
$\pm$ Roll	0.9	$\pm$ 0.2	1.5	$\pm$ 2.6	0.3	$\pm$ 0.2
Landing	0.2 $\pm$ 1.3	$\pm$ 0.7	2.0 $\pm$ 2.0	$\pm$ 0.2	$\pm$ 0.2	$\pm$ 0.1

The accelerations result from the dynamic response of the instrument to the acceleration factors experienced by the integrated Shuttle/Spacelab vehicle and are a function of the mass location and stiffness distribution. Actual instrument accelerations of various Spacelab configurations will be established by means of coupled Shuttle/Spacelab/instrument dynamic analysis.

Steady state crash accelerations are given in Table 3.5-4. These accelerations are applicable only to the mounting and attachment structure of large instruments, their attachment fasteners and local surrounding structure (e.g., bearing structure around bolt-holes). Crew compartment interior crash accelerations are also included on this table, being applicable to mounting structures for equipment and crew provisions in the crew compartment.

Crash accelerations act separately and are ultimate. The longitudinal accelerations are directed within a cone of 20^{o} half angle from the longitudinal (X) axis.

Instruments should be capable of normal operation after being subjected to acceleration for each of the mission events except for crash landing.

Table 3.5-4 Ultimate Crash Load Factors

	Total Accelerations (G)					
+X	+X	-X	+Y	-Y	+Z	-Z
Crash Landing Loss	9.0	1.50	1.50*	1.50*	4.5	2.0*
Crash (Crew Interior)	20.0	3.30	3.30*	3.30*	10.0	4.4*

*Superseded by 20^{o} half cone angle misalignment of axial crash loads

3.5.2.6 REACTION CONTROL PLUME ENVIRONMENT

The Reaction Control Subsystem (RCS) employs bipropellant thrusters using monomethylhydrazine (MMH) as the fuel and nitrogen tetroxide (N_2O_4) as the oxidizer. Two thruster sizes are used: (1) primary RCS engines operating at a nominal rated vacuum thrust of 870 pounds to provide attitude control and translational capability, and (2) vernier RCS engines operating at a nominal rated vacuum thrust of 25 pounds to provide more precise attitude control capability.

3.5.2.6.1 PRIMARY RCS THRUSTER PLUME

There are 14 primary engines located in the forward RCS modules and 24 in the OMS pods. Figure 3.5-5 shows the gas plume flow field and constituents of the combustion products for a primary engine. The mass fraction, major constituents, sizes, and potential contamination are listed on the right of the figure. Figure 3.5-6 shows the 92 percent streamline of the gaseous phase plume. Figure 3.5-7 shows the RCS thruster 95 percent plume geometry.

3.5.2.6.2 VERNIER RCS THRUSTER PLUME

The vernier RCS consist of six engines. Two are located in the forward RCS module adjacent to the primary thrusters (one on each side) and fire in the down (-Z) direction. Four (two on each side) are located aft on the OMS pods. Two fire sideways, one in the +Y

and one in the -Y direction, the other two fire in the downward (-Z) direction. Figure 3.5-8 shows the vernier thruster 95 percent plume geometry.

3.5.2.7 THERMAL ENVIRONMENT

The determination of the temperature environments which the payload will actually experience in the payload bay requires knowledge of the specific mission environment from boost through entry, the type of thermal control provided by the Orbiter and the payload, and the payload bay and payload thermal characteristics. To obtain this information requires detailed knowledge of the actual Orbiter and payload design, as well as the specific inflight orientations which probably will vary for each different mission objective.

Data for this section will be provided by the prime contractor as a result of Phase C/D thermal analyses.

3.5.3 FLIGHT ENVIRONMENTS (PRESSURIZED MODULE)

This section will provide similar information to Section 3.5.2 for instruments mounted internal to the Spacelab module.

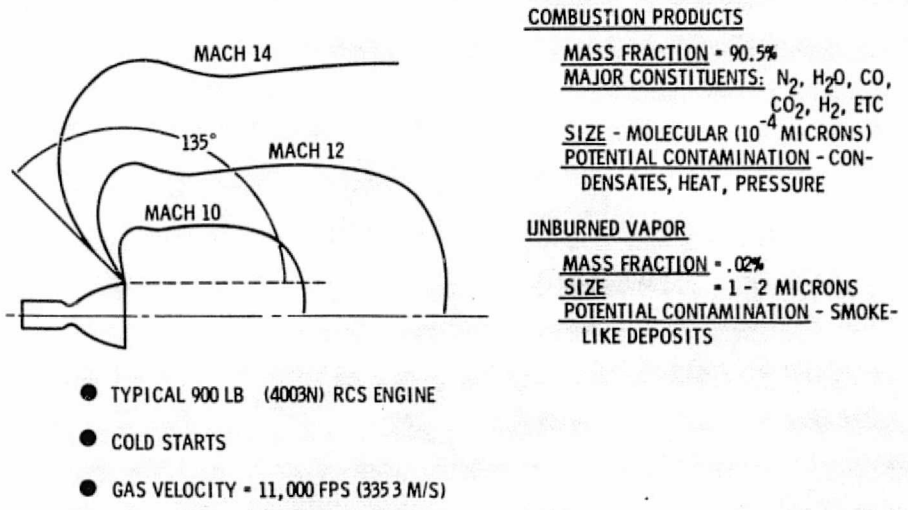


Figure 3.5-5 RCS Gas Plume Flow Field and Constituents

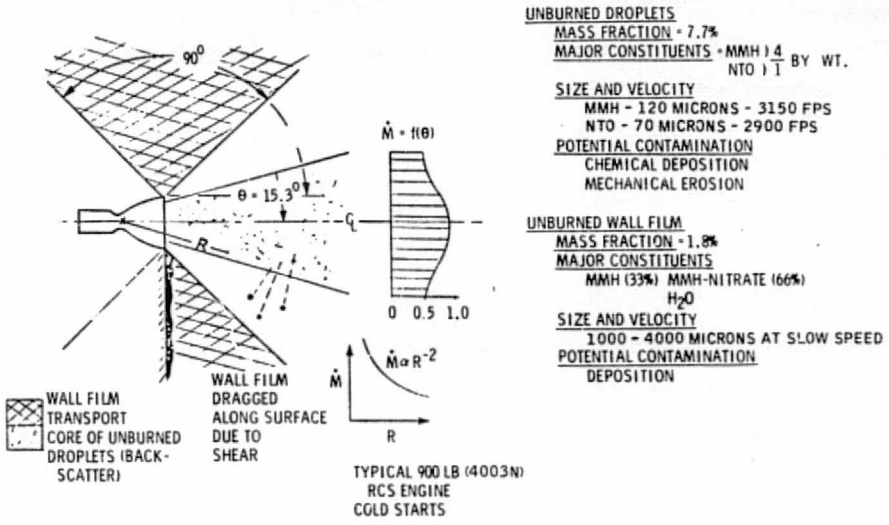


Figure 3.5-6 RCS 95% Streamline of the Gaseous Phase Plume

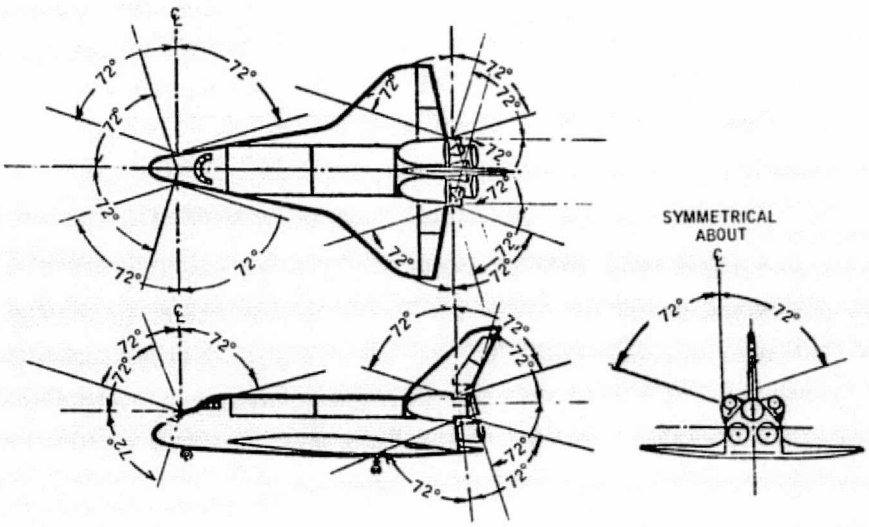


Figure 3.5-7 RCS 95% Gas Phase Plume Envelope

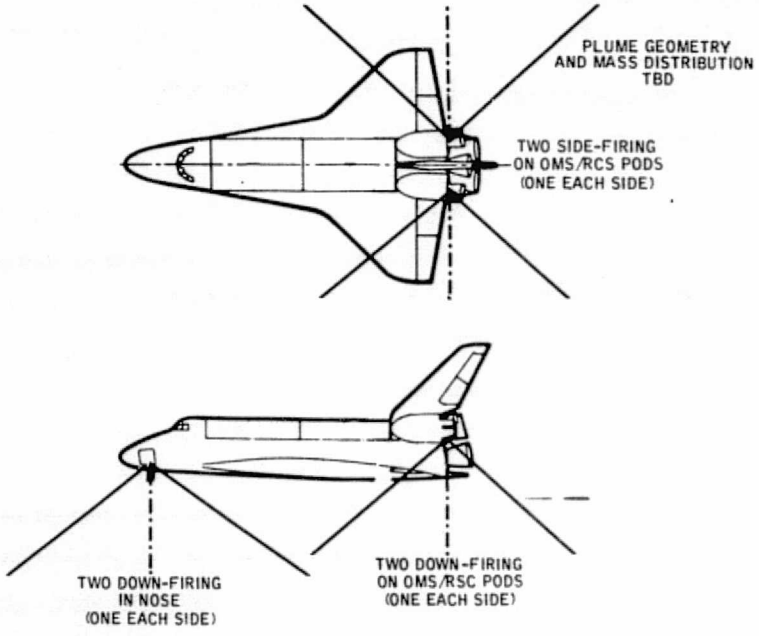


Figure 3.5-8 Vernier RCS 95% Gas Phase Plume Envelope

3.6 DATA MANAGEMENT AND CONTROL

3.6.1 DATA ACQUISITION AND CONTROL INTERFACES

The principal interface between the AMPS to instrument interface shall be the Remote Acquisition Units (RAU). This interface shall be used for bidirectional data transfer from the computer/C&D station to the instrument. Data transfer from an instrument shall not exceed 100 kbps. Data not required onboard shall be routed directly to the high rate multiplexer wherever practical.

3.6.1.1 RAU INTERFACE

Simplification of the data and command interface shall be a primary goal of instrument design. Each instrument shall be allocated data and command lines not to exceed the following:

Parameter	Primary Functions	No. Channels
Serial Data Channel	Science and operational data required by computer, CRT or ground. To be less than 100 kbps.	1
Analog/Discrete Input	Non-operational monitor of instrument	32
Serial Command Channel	Instrument control	1
Discrete Commands	Backup to hardwired commands	16

Instruments requiring additional channels shall negotiate their requirements with the AMPS prime contractor.

3.6.1.1.1 SERIAL DATA INTERFACE

Serial data transfer shall require three lines, a data line, a clock line and a user request line. The serial word block size transferred at any one time shall not exceed 32. Signal characteristics shall be as shown in Figure 3.6-1 and as follows:

Data Line

Signal type	complementary
Digital "one" signal time-to-ground	+2.5 to +4.5 V (high state)
Return line-to-ground	-0.5 to +0.5 V (low state)
Digital "zero" signal line-to-ground	-0.5 to +0.5 V
Return line-to-ground	+2.5 to 4.5 V
Impedance	83 Ω maximum
Fault voltage emission	±15 V maximum (line-to-ground, as a result of any single-point failure)
Fault current	±15 ma maximum
Distortion (overshoot, ringing)	0.25 Vp (line-to-ground positive) 0.15 Vp (line-to-ground negative)
Bit rate	1 Mb/s ± 0.1 percent
Block size	maximum 32 16 bit + parity bit words

Request Line

Source	
Signal type	single-ended or differential
Digital "zero" signal	0 ± 0.5 V
Digital "one" signal	+ 5 ± 1.0 V
Rise/Fall Time	less than 2.0μs (measured between 10 and 90 percent of the peak signal values on a load of 50 kΩ in parallel with 2500 pF)
Output Impedance:	1 kΩ maximum at DC in either logic status
Driving capability	50 kΩ minimum in parallel with 2500 pF maximum
Fault voltage emission	± 10 V maximum
Load	
Input type	differential, isolated
Digital "zero"	+2.0 V to -0.5 V
Digital "one"	+2.5 V to +6.0 V
Impedance	500 kΩ minimum (line-to-ground shunted with 200 pF maximum)
Power-off-impedance	2 kΩ Minimum (measured line-to-line with a differential signal of 5 V and a common-mode signal of 5 V)
Fault voltage emission	±15 V maximum (line-to-ground as a result of any single-point failure)
Fault current limitation	±15 m A maximum

Clock Line

Same source and load characteristics as Data Line.

3.6.1.1.2 ANALOG/DISCRETE INPUTS

Analog Inputs

Input Signal	Balanced or single ended
Signal Range	-5.12 V to +5.08 V
Common Mode Voltage	±6 V
Encoding Format	8 bits
Output Impedance	1 K ohms at DC to 500 Hz
Driving Capability	200 KΩ min in parallel with 2500 pF max

Discrete Inputs

Signal type	Single ended or differential
Digital "zero"	0 ± 0.5 V
Digital "one"	+5.0 ± 1.0 V
Output Impedance	1 K ohms at DC
Driving Capability	50 KΩ min in parallel with 2500 pF max

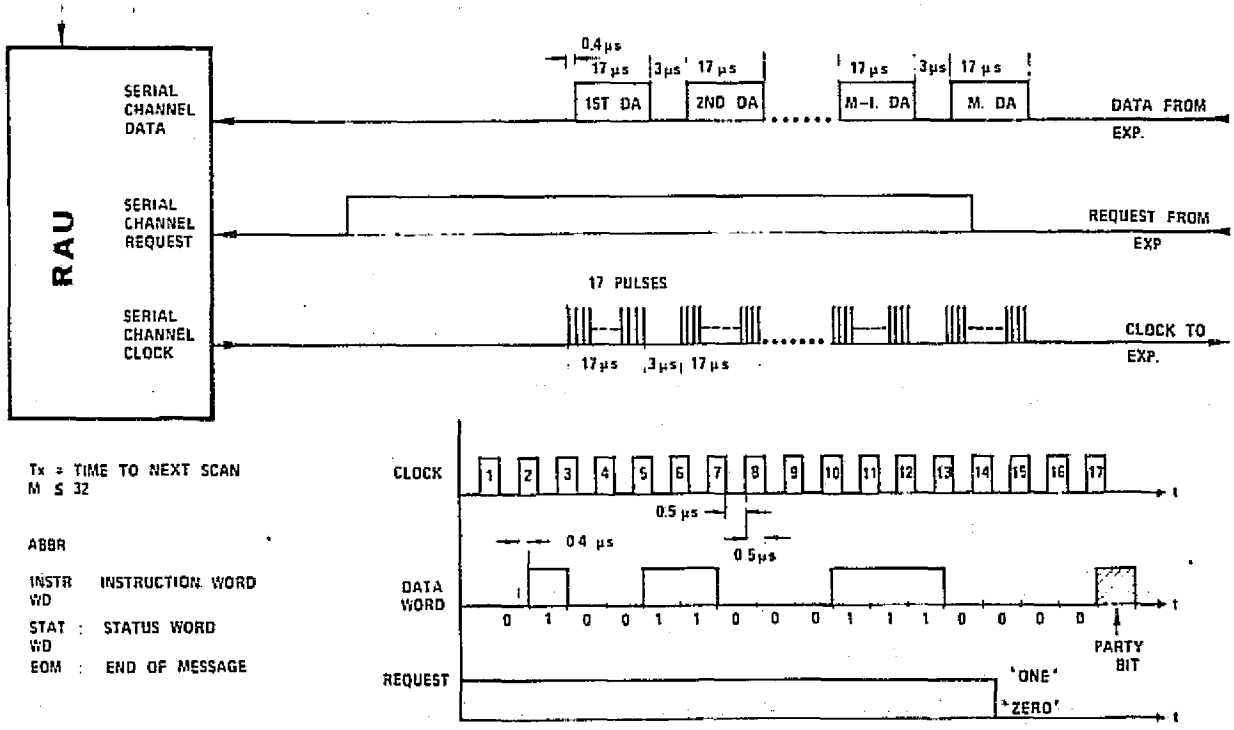


Figure 3.6-1 Serial Data Channel Interface

3.6.1.1.3 SERIAL COMMANDS

Serial commands from the RAU to the instrument shall require two lines, a command line and a clock line. In addition to commands, this line will be used to transfer to the instrument software generated data as GMT, Orbiter state vector data and ground data. Signal characteristics shall be as follows and as illustrated in Figure 3.6-2.

Serial PCM Command Line

Code - NRZ-L

Other characteristics shall be the same as the Data Line of 3.6.1.1.1

Clock Line (RAU to Instrument)

Clock Rate - 1 MHz clock frequency

Other characteristics shall be the same as the Data Line of 3.6.1.1.1

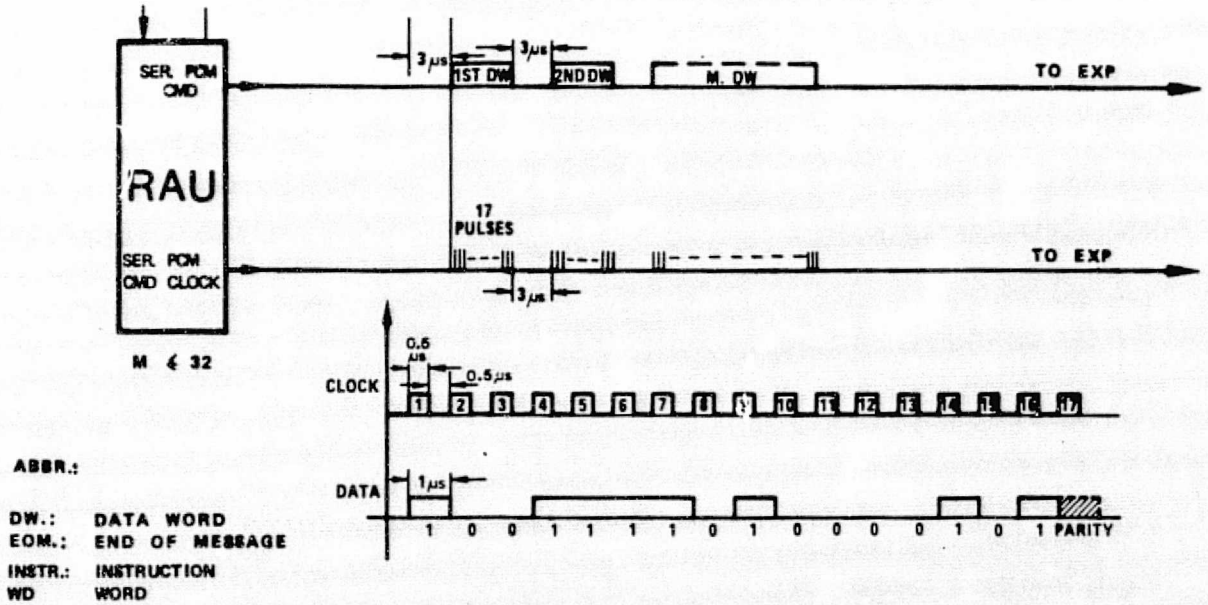


Figure 3.6-2 Serial Command Channel Interface

3.6.1.1.4 DISCRETE COMMANDS

Source

Signal type	single-ended
Digital "zero" signal	0 ± 0.5 V
Digital "one" signal	+ 5V ± 1.0 V
Rise/fall time	less than 100 μs (measured between 10 and 90 percent of the peak signal values and on a load of 10 K in parallel with 1000 pF)
Driving capability	20 mA minimum
Pulse duration	30 mA minimum
Fault voltage emission	±15 V maximum (line-to-ground, as a result of any single-point failure)

Load

The instrument load shall be either an OP Amp or an OPTO Coupler with the following characteristics:

OP Amp

Input type	Differential isolated
Digital "zero" state	+2.0 V or less
Digital "one" state	+2.5 V or greater
Impedance	50 KΩ minimum (line-to-ground, shunted with 200 pF maximum)
Power-off impedance	2 KΩ minimum (measured between line-to-line with a differential signal of 5 V and a common mode signal of 5 V)
Fault voltage emission	+10 V maximum (line-to-ground)
Fault current limitation	+20 mA maximum
Common mode rejection	$-10\ V \leqslant V_{cm} \leqslant +10\ V$ (DC to 500 Hz line-to ground on both signal terminals shall not activate receiver circuits)

OPTO Coupler

Input type	Isolated
Digital "zero" state	+1.5 V or less
Digital "one" state	+3.0 V or greater
Input current	15 mA maximum at 5 V
Input capacity	200 pF maximum (line-to-line)
Fault voltage emission	±10 V maximum (line-to-ground, as result of any single point failure)
Fault current limitation	±20 mA maximum

3.6.1.1.5 TIMING INTERFACE

In addition to the transfer of GMT serial data to the instrument via the serial command line, a 1024 KHz and a 4 Hz update output shall be available from an RAU. These signals, in conjunction with GMT, shall provide for data tagging to an absolute accuracy of 1 millisecond. A 16 bit word indicative of this acquisition time shall be interleaved with the data word for precise time calculation by the experiment computer. The 1024 KHz and 4 PPS pulse shall be derived from the same source as GMT and shall have the following characteristics.

Source and Load characteristics shall be as specified in the Data Line of 3.6.1.1.1.

Clock

1024 KHz

Clock Update

4 PPS

Pulse width 10 μs ± 1 μs

3.6.1.2 HI-RATE MULTIPLEXER INTERFACE

It shall be the responsibility of the instrument to multiplex on one data stream all science, engineering and other corollary data required for post flight data analysis. This serial data shall interface with the hi-rate multiplexer input. The HRM provides 16 experiment input channels with allocated bit rates variable in binary ratios. Four (4) different types of experiment input channels with different dynamic range are defined:

- o 2 inputs from 16 Mb/s to 62.5 kb/s
- o 2 inputs from 8 Mb/s to 62.5 kb/s
- o 4 inputs from 4 Mb/s to 62.5 kb/s
- o 8 inputs from 2 Mb/s to 62.5 kb/s

The code for the input data shall be NRZ-L plus clock.

The signal interface requirements are TBD.

3.6.1.3 VIDEO INTERFACE

Video signals generated by an instrument at the AMPS interface shall be compatible with U.S. commercial black and white video format defined in EIA specifications RS170 and RS330, modified as follows:

Composite Video Requirements

Frame Rate	29.97 Frames/Sec
Lines per Frame	525 (interlaced)
Aspect Ratio	4/3

Horizontal Scanning Frequency	15,734.264 Hz
Vertical Scanning Frequency	Horiz Freq/262.5
Composite Video Bandwidth (3 db)	4.5 MHz
Fields	60 interlaced fields/sec

Sync signal shall be provided to the instrument video system and shall have the following interface requirements:

Voltage	1 V P-P $\pm$10%
Source Impedance	75 ohms
Load Impedance	75 ohms
Waveform characteristics	TBS

The output video signal interface requirements shall be as follows:

Voltage	0.9 to 1.10 P-P
Video Signal/Noise Ratio	TBD
Impedance	Video input and output impedance shall be 75 ohms $\pm$5%
Signal Grounds	The video and sync signal returns shall be isolated from vehicle ground, Spacelab ground and power ground by at least 1.0 Megohm

The composite waveform shall conform to that described in the Shuttle Vehicle/Spacelab Avionics Interface ICD-2-05301.

3.6.1.4 WIDEBAND ANALOG SIGNAL INTERFACE

Instruments with widebard analog signals shall provide the following capability.

Output Signal Level

Load Impedance

TBS

Bandwidth

Signal to Noise Ratio

The instrument output circuit shall be capable of driving a line of 80 feet maximum.

3.6.1.5 MDM INTERFACE

This paragraph will identify the signal interface requirements for instrument measurements that are required to be hardwired to the Orbiter MDM because of crew safety, activation/deactivation or caution and warning requirements.

3.6.1.6 DEPLOYED PACKAGE INTERFACE

This paragraph will contain interface requirements between AMPS provided PCM encoders, FM voltage controlled oscillators, command decoders and the instruments.

3.7 CONTROLS AND DISPLAYS

This section will define the AMPS to instruments C&D interfaces. The unique ICD interface documents will contain the functional interfaces between crew and the instruments. Additionally, this section

of the unique instrument ICDs will incorporate hardware and software instrument interfaces.

3.7.1 CONTROLS

This section will define each instrument dedicated control and describe the function of each control to the level that each command to the instrument. It will note whether controls are discrete, continuous, multiple position, etc.

3.7.2 DISPLAYS

This section will define each instrument dedicated display and describe every discrete function of each display. Included will also be displays on the CCTV and the oscilloscope.

3.7.3 FUNCTIONAL INTERFACES

This section will present a brief functional analysis of crew and AMPS instrument interfaces. Also included here should be use of Spacelab keyboard and CRT.

3.7.4 INSTRUMENT SOFTWARE INTERFACES

This section will define all instrument software interfaces to the Spacelab Computer, CRT, etc.

3.8 RF INTERFACES

This section will describe RF interfaces of AMPS instruments including specific RF transmit and receive frequencies, power levels, fields-of-view, data rates, signal bandwidths, modulation signal format, etc.

3.9 INSTRUMENT POINTING INTERFACES

This section will define pointing requirements at the AMPS instrument interfaces.

3.9.1 INSTRUMENT ORIENTATION AND ACCURACY

If a specific orientation of an instrument is required with respect to inertial space, local vertical, B-field vector, Earth's limb, etc., it will be specified here. The pointing accuracy and stability of the instrument's line-of-sight to each target and the time duration anticipated will be specified. If more than one target is anticipated, each should be described.

3.9.2 INSTRUMENT ANGULAR RANGE

If an instrument is required to scan or point to more than one target to satisfy an experiment, the angular range of operation will be included here.

3.9.3 INSTRUMENT ALLOWABLE RATES

This section will describe the allowable rates to the instrument interface during the performance time described in 3.9.1.